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THE ANALYSIS ON HOW THE MATERIAL FROM A STEAM BOILER'S ECONOMIZER BEHAVIOR AT ELEVATED TEMPERATURE

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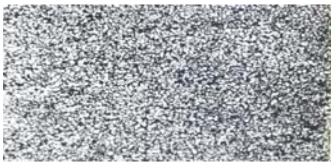
ABSTRACT
The paper presents the results of experimental research on OLT 45K steel, in two alternatives of utilization. Thus, tensile test at elevated temperature has been done on test piece cut from a steam boiler's economizer and on test piece cut from an unused tube, which was about to be assembled in the boiler. The obtained experimental results allow the establishment of the mechanical characteristics (of strength materials), at different elevated temperature, adherent to the operational temperature, for the analyzed type of steel.
Keywords: mechanical testing, high temperature, non-alloy steel.

1.GENERAL CONSIDERATIONS
This study has started from the idea that *"many aspects of the materials' behavior, in real operational conditions, are still exterior to the theoretical knowledge and they cannot be successfully studies only by experimental techniques, and any study of the materials' behavior, in well-specified conditions, is unfinished without the completing of the theoretical knowledge with experimental data, obtained by laboratory research."*
OLT 45K steel –STAS 8184-80 is non-alloy steel category, used for the manufacturing of tubes that work at elevated temperature. Specimen from this type of steel has been taken from tubes that have worked in a steam boiler; test piece cut have been drawn from the economizer, the material being OLT 45K. Also, test piece cut have been drawn from unused material of the same type of steel.
The drawing of test piece cut has been done very carefully, so as to observe these test-bars' shape, which has a calibrated length, by techniques of splinting mechanical work and not to influence the structure of these materials. Also, ring-shaped transversal samples have been drawn for metalographical analysis, looking at emphasizing the morphology of transformation stages from the material, and establishing the seed size, likely oxidation or decarburization phenomena and other structure faults. The results of these metallographic analyses continue to be presented, and the chemical structures of the analyzed steel are shown in table 1, together with a comparison to the adherent product's standard. After the metalographical analysis, it is found that the tested material is part of the adherent standard, but stating that small size of molybdenum can be detected. Analysing this fact, in accordance with [2], we can state that, in small amounts, molybdenum is fighting against the reversible return brittleness. Disolved in ferrite and forming carbides, molybdenum improves the resistance features and to a certain extent, the plasticity features of annealed or normalized steel, just like the case at study. Molybdenum also improves the usage resistance and stops the sliding process, by forming carbides, ascertaining a sensitive growth in the steel resistance at high temperature.

Table 1. The results of the chemical analysis of the material that has been taken from the economizer and of the unused material (38 mm diameter tube, having a 3.5 mm thickness)

Material	**C**	**Mn**	**Si**	**S**	**P**	**Cr**	**Ni**	**Cu**	**Mo**
	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]
Economizer	0,23	0,62	0,25	0,031	-	0,22	0,21	0,18	0,30
Unused material	0,21	0,46	0,27	0,005	-	0,17	0,14	0,20	0,28
STAS 8184-80	Max. 0,23	Min. 0,45	0,15… 0,35	Max. 0,045	Max. 0,040	Max. 0,30	Max. 0,30	Max. 0,30	-

Therefore, molybdenum is the ally element that provides the mechanical resistance of steel used at high temperature. For the tube material drawn from the economizer, shown in fig. 1, after the study performed with an optic microscope, it has been noticed that this one gives a feritte-perlite structure, with thin grains (fig.1.a), and the tube walls have a modified structure on the exterior wall of the tube, which means that a carburizing is present at the limit area, but it does not harm the functioning of that particular element. (fig.1.b)



a

b

Figure 1. The structure of the tube drawn from the steam boiler's economizer

Figure 2. The structure of the tube drawn from the unused material

For the tube material drawn from the tube that was about to be replaced, after the study performed with an optic microscope, it has been noticed that this one gives a slightly heated feritte-pelite structure (the feritte is acicular-shaped and not grain-shaped, as it usually is), probably because of the testing made at the tube's delivery by the manufacturer, as it is shown in fig. 2.

From the metallographic analyses one can conclude that it is because in the structure of the analyzed steel a sufficient perlite and ferrite quantity is being kept, and the thin granulation noticed in these structures can make us say that the materials still give great mechanical characteristics, and this is a reason for which they can continue to be used.

2.THE TESTING ACHIEVEMENT

The mechanical characteristics guaranteed on the products delivered as tubular, established on the specimen for testing which have been drawn longitudinally, in the conditions of the ambient testing atmosphere, are shown in table 2.

Table 2. The guaranteed mechanical features for OLT 35K steel

Steel type	**Tensile strength** R_m **[N/mm²]**	**0,2% proof strenght** $R_{p0,2}$, **[N/mm²], min.**	**Percentage elongation after fracture** A, **[%], min**	**Percentage reduction of area** Z, **[%], min.**	**Resilience** KCU 300/2 **min.**
OLT 45K	450…550	260	21	60	60

In the field of high temperature, driving testing has been made on a universal machinery by adjusting a genuine conception of heating precincts, presents in [1]. The testing made for establishing the mechanical driving features have taken place between +20°C...+500°C, at different levels of temperature. Some used specimen for testing that contain material drawn from the economizer, unused material, are shown in fig. 3 and fig. 4.

Figure 3. Specimen for testing, drawn from the economizer's material

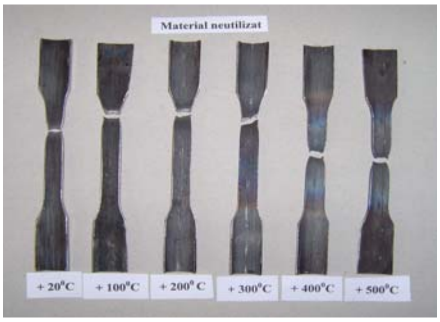


Figure 4. Specimen for testing, drawn from the unused material

3.THE RESULTS EXAMINATION

The values of the resulted mechanical characteristics are synthesized in table 3 and 4. The values in the chart give the average of the mechanical characteristics obtained from the sets of three specimen for testing, tested at each level of temperature.

Table 3.The drive mechanical characteristics of the steel taken from the economizer

Testing temperature [^{0}C]	Maximum force F_{max} [N]	Tensile strenght R_m[N/mm^2]	Percentage elongation after fracture A[%]	Percentage reduction of area Z [%]
20^{0}C	25150	574,85	58,75	40,54
100^{0}C	27350	625,14	43,75	20,80
200^{0}C	25900	592,00	43,75	34,81
300^{0}C	25350	579,42	52,50	23,47
400^{0}C	20400	466,28	50,00	46,78
500^{0}C	11300	258,28	31,25	48,89

Table 4. The drive mechanical characteristics for the unused material

Testing temperature [^{0}C]	Maximum force F_{max} [N]	Tensile strenght R_m[N/mm^2]	Percentage elongation after fracture A[%]	Percentage reduction of area Z [%]
20^{0}C	28500	659,42	66,25	37,00
100^{0}C	30400	694,85	37,50	17,62
200^{0}C	29200	667,42	38,75	21,50
300^{0}C	34700	793,14	43,75	21,55
400^{0}C	22000	502,85	37,50	29,78
500^{0}C	16900	386,28	27,50	53,92

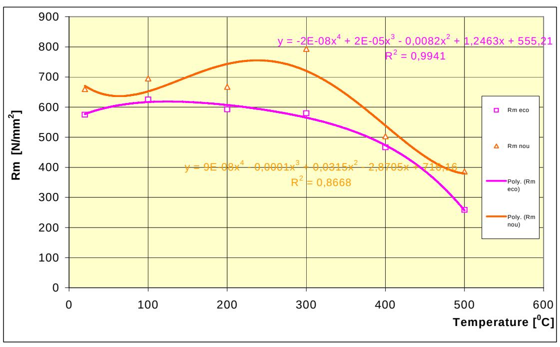


Figure 5. Variation R, with the temperature, for OLT 45K steel, in two alternatives of utilization

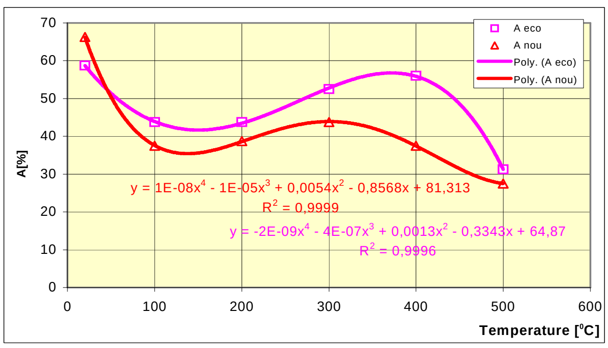


Figure 6. Variation A with the temperature, for OLT 45K, in two alternatives of utilization

Given the data in table 4 and 5, there have been drawn variation diagrams of the drive mechanical characteristics for OLT 45K steel, taken from the economizer, and OLT 45K, unused material, varying with the testing temperature. Therefore, fig. 5 shows the variation of the Rm characteristic, fig. 6 shows that of the A characteristic and fig. 7 – Z variation.

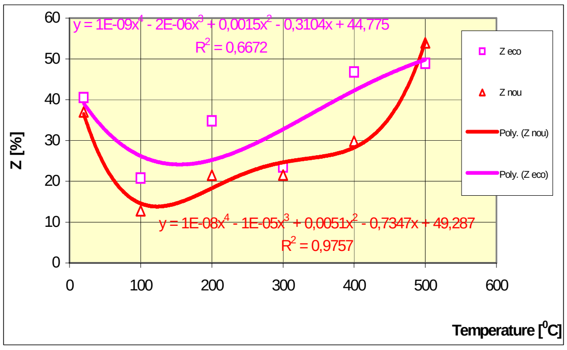


Figure 7. Variation of the Z value, with the temperature, for OLT 45K, in two alternatives of utilization

From the analysis of the obtained results, fig.5 it can be clearly noticed that the tensile strenght of the unused material is superior to the used one, taken from the economizer;

By analyzing the percentage elongation after fracture chart, fig. 6, one can establish that this one has higher values, for the used material, compared to the value for the unused material. It can be noticed that high temperature influences the variation curve, changing its propensity between 100 - 200°C.

The Z value has higher values fro the used material and obviously lower for the unused one, but tested in conditions of high temperature.

4. CONCLUSIONS

The crucial area is somewhere between 100°C … 150°C, which is specific to these types of steel, with low carbon content, that becomes fragile at static requirements, on such temperature (fragility to blue).

The testing performed on OLT 45K steel, for every experimental variation, has underlined some differences among the mechanical characteristics of the steel (after certain periods of utilization) to the initial state (unused). The explanation consists in the fact that the variation of the temperature, characterized by a reduced thermal gradient, has influence on the material's behavior, in different operational conditions, which can be confirmed by the mechanical testing that has been done.

Analysing the appeaance of the broken test-bars surface, you can say that temperature influences the critical tangen tension value from the sliding layouts and especially the diffusion process of carbon, so that at a temperature between 250...300°C, the diffusion speed of carbon atoms is great, which makes the dislocation movement possible (in accordance with Ludes lines), that are taking place in the material.

Following the metalographical analysis and the testing, it can be concluded that materials still offer great mechanical features, as in the structure of the analysed steel there is a sufficient quantity of perlite and ferrite and fine granulation, which gives an important reason for continuing their exploitation.

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